turbance of the potential gradient, associated with 17 storms which passed over the station, preceded the first rain (taken as indicating the arrival of the storm) by periods ranging from 3 to 109 minutes and averaging 46 minutes. In 6 cases the rate of travel of the storm was known, the average being 33 km. per hour, yielding an average distance at the time of the first disturbance of the gradient of 33 km. Of the storms which passed at a distance from the station, some were associated with rain at the station and others not. Of the former, the first disturbance of the gradient preceded the rain by intervals ranging from 0 to 42 minutes. From the forecasting point of view, however, the first disturbance of the gradient by a thunderstorm can not be distinguished from disturbances due to minor causes. The author goes on to consider the time at which the gradient has reached a certain value as a criterion of the approach of a storm and reaches the conclusion that it is within the bounds of possibility to receive a warning of half an hour to one hour by observations of the potential gradient considered in relation to its normal course. This warning will usually precede the first thunder heard. The instruments used at Leipzig are described, and the mean diurnal variation of potential gradient for each month and the seasonal variation for the period Jan., 1913, to July, 1914, are included in the paper.—*M. A. G.*

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INVESTIGATIONS ON LIGHTNING DISCHARGES AND ON THE ELECTRIC FIELD OF THUNDERSTORMS.[1]

By C. T. R. WILSON.

[Abstract of discussion at the Meteorological Office, London, by G. C. Simpson, Nov. 20, 1920; reprinted from *The Meteorological Magazine*, London, March, 1921, pp. 242-243.]

Mr. Wilson has invented very ingenious apparatus by which rapid changes in electric force near the ground are recorded, and he has obtained records which show how the electric field varies during a thunderstorm. Between two lightning flashes the change in the force is gradual, an asymptotic approach toward a limit, but when a flash occurs there is a sudden change in the field. In the flash equal positive and negative charges run together and the electric moment which is proportional to the magnitude of these charges and their distance apart can be estimated from the record. It is found that the charges are of the order of 20 coulombs. According to Mr. Wilson, the clouds may carry either negative charges above and positive below or positive above and negative below. Dr. Simpson demonstrated, however, that the new evidence was consistent with his own theory, according to which the electrification, being due to the breaking up of drops, was always negative above and positive below. He criticised with some severity an extension of Wilson's theory which purported to explain the normal fine-weather potential gradient as a by-product of thunderstorms.

In the subsequent discussion Dr. Chree explained the bearing of these researches on the growth of crops under electric stimulus. Sir Napier Shaw emphasized the desirability of obtaining simultaneous records from three or more stations during the progress of a storm.

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LIGHTNING EXPLODES TREE AND DIGS TRENCHES.

On the night of December 20th, at 7:30 p. m., a thunderstorm came up from the southwest, with occasional thunder about 7:45 p. m. A vivid flash of lightning lighted up the darkness about as much as a brilliant light in a room.

A fraction of a second after the first thunderclap an explosion took place in my telephone. The report was equal to that of firing a shotgun in the room with a charge of three drachms of powder. I immediately investigated the telephone and a strong odor as of burning powder was escaping from it. I could see no damage to the phone, but it failed to operate.

On the morning after the storm I went out to look along the telephone line. Sixty-four rods west of the house I found that a tree had been struck by lightning 100 feet north of the telephone line.

The tree was about 15 or 20 inches in diameter at the ground and about 50 feet high, as near as I could estimate its height. The entire body of the tree was riven into pieces and none of it left near the place where it had been standing. About 18 feet of the top with many branches intact lay immediately over the place where the tree stood. What remained in the ground was torn

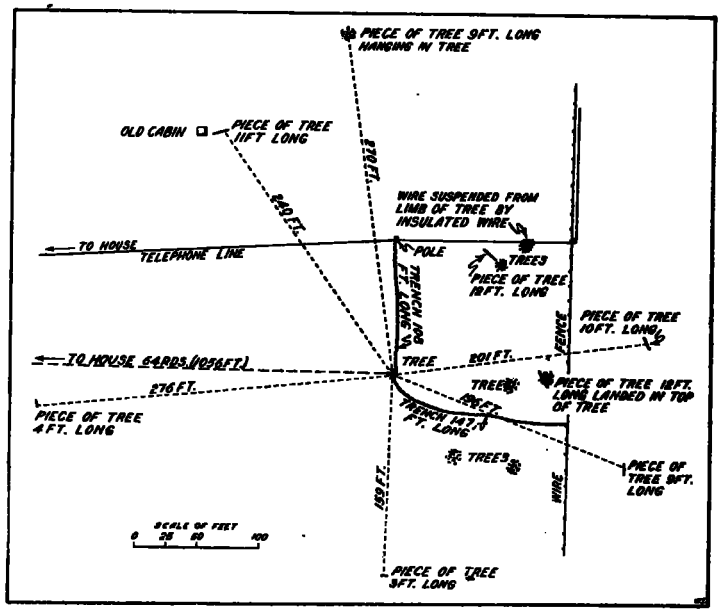

FIG. 1.—Lightning-stroke dispersion of tree-splinters and course of root trenches. (A. F. Stevens, Gravette, Ark.)

off at the surface of the ground, but was riven and shivered into slivers.

The telephone pole 100 feet south of the tree was shorn off at the top of the ground and lay some 50 feet southwest of its original position, riven into slivers.

But what surprised me most after looking over the area over which the body (of the tree) lay strewn was what I have marked "trenches" on the rude plat I am inclosing. [Fig. 1.] These start at the stump of the tree and run in directions indicated by solid lines and marked "trench." The one running south is 108 feet long, a little longer than a direct line from the stump to the telephone pole and ends abruptly at the pole with but little disturbance of the earth on the south side of the pole. What I call trench is not a clean dug trench. In places there have apparently been explosions that have thrown out much dirt; again it was heaved up like the dirt along where a mole has heaved up a runway. Some places it is widely cracked open along the middle of that portion of the earth that lies highest or is raised highest. It runs in a sinuous line as I have tried to draw it. The other trench is 147 feet long, starts out from the stump in a northerly direction, then curves to the left and takes

[1] Phil. trans. Roy. Soc. London, 1920, Ser. A, 221: 73-115.

almost a straight line with but slight sinuosity in a west by northwest direction and ends up at the wire fence as abruptly as the south trench does at the telephone pole.

I have indicated on the plat by short, solid lines the position and length pieces of the tree, and by broken lines the direction the pieces must have taken as they were catapulted by the explosion. The largest piece of the tree body hangs to a tree northeast of the tree to which the telephone line was attached. It is about 12 feet long and perhaps 8 inches by 6 inches in diameter.

The ends of the telephone wire at the pole standing near the wire fence was apparently melted in two. Also, the wire that held the main wire to the insulator on the post was about one-half melted away and reduced in size.

What is puzzling to me is why it seems to end so abruptly at the pole and the fence, there apparently being no diminution in the electrical force in the trench which ends so abruptly. The ground along the trench is broken up about 15 or 20 inches in width with occasional open trench 12 to 14 inches wide and from 4 to 10 or 12 inches deep. I did not measure the length of any of the open trenches, but think they would run from 6 to 15 feet in length.

I took a 1¼-inch bar about 6 feet long * * * and sounded the trenches for their full length. On dropping the heavy bar it would sink of its own weight to the bottom of the trench, the ground being so well broken up. The ground has never been broken up since clearing but has been in pasture ever since. * * * The measurements of the trench showed a minimum depth of 28 inches, a maximum of 32 inches. The ground is very compact, the bar striking on the bottom as if on solid rock. The tree was green, a post oak, and from examination of the larger pieces shows that it was decayed at the heart up to where the top broke off whole and came down over what was left in the ground. The solid wood around the decayed heart is about 7 or 8 inches thick. The stump that was left in the ground, also the telephone pole stump, shows but little effect of the stroke, being cut off nearly square. * * * The wire was melted in two many rods west of the pole that was blasted. The telephone pole had no ground wire and the lower wire of the fence was 6 inches above ground. The trench running west to the fence stopped directly against the fence post in the same manner that it did at the telephone pole, but the fence post suffered no damage except to be slightly loosened in the ground. The ending of each trench at the telephone pole and fence post to all appearances ended up with about the same force, showing about the same eruptive force and the same depth, yet one was torn off and the other uninjured. In carefully looking over the ground within 100 feet of the blasted tree the ground was littered with hundreds of small bits of wood from an inch to several inches long and from one-fourth to an inch in thickness. The decayed portion looked as though it had been coarsely ground up and widely scattered.—*A. F. Stevens*, Gravette, Ark.

During a severe thunderstorm recently near Milldale, Warren County, Va., a bolt of lightning after shattering a large tree ran down into the roots and plowed furrows a foot deep for 25 feet in every direction. The bolt was so severe that many panes of glass in a near-by house were shattered, even where the outside blinds were closed.[1]

[1] From report in Washington, D. C., *Evening Star*, May 5, 1921.

UNUSUAL LIGHTNING.

By ROBERT E. HORTON.

[Voorheesville, N. Y., October, 1920.]

On the evening of Sunday, September 5, 1920, between 6 and 7 p. m., the writer observed unusual forms of lightning at his laboratory near Voorheesville, N. Y. A severe thunderstorm was approaching from the northwest. This storm came down the Mohawk Valley, passing Utica about 4 p. m. The storm clouds spread out far to the south and east from the storm itself, in apparently a nearly horizontal layer of only moderate thickness and height, but very uniform. Clear sky could be seen to the west and southwest over the Helderberg escarpment.

From the writer's position he could observe the storm approaching from a distance of many miles. Lightning bolts passed frequently from the clouds to the ground, or vice versa, in very nearly straight vertical lines. At the same time, branching forks of lightning would spread out from the point of issue of the main bolt in all directions from the place where the earth charge left or entered the clouds. Apparently most of these forked branches shot out horizontally between the east and northeast. That may, however, have been an effect of perspective. Commonly two or three horizontal branches would strike out along the under surface of the clouds, and each would subdivide sometimes into four or five minor branches, the branches traversing a horizontal angle relative to the observer of 20° or 30°, and then dying out.

On two occasions what appeared to be balls of lightning shot horizontally from the eastern to the western portion of the horizontal cloud layer, apparently traversing the under surface of the cloud. These balls of lightning were at a great distance, and as they traversed an angle relative to the observer of 30° to 45°, their distance of travel must have been several miles. Their velocity appeared to be much slower than that of lightning. They were apparently unaccompanied by thunder, and occurred intermediate between the occurrence of the other lightning flashes described.

The forked, horizontal lightning above described was observed by several persons who were with the writer at the time. Unfortunately, none of these persons happened to notice the ball lightning. The writer is certain, however, that this was not an optical illusion, especially in view of the fact that both the balls of lightning referred to disappeared as they passed behind a barn within the range of the writer's vision and then reappeared on the other side.

Mr. George T. Todd, local forecaster, of the U. S. Weather Bureau, states that he observed the same storm and noted the peculiar horizontal, branched and forked lightning, but did not see the ball lightning. He watched the storm while traveling by automobile from Gloversville to Albany during the hours 6 to 8 p. m. Herbert E. Vail, assistant, U. S. Weather Bureau, Albany, states that during the same storm he observed a ball of lightning fall and strike the ground between his house in Albany and an adjoining house.